

Alerts to Student Difficulties and Misconceptions in Science

Some students will fail to learn ideas because the subject matter material may be at a level that does not match the developmental learning stage of the student or the student may hold on to tenacious alternative conceptions (sometimes referred to as misconceptions) that were not identified prior to instruction and considered during the stages of instruction. Curriculum, instruction, and assessment are significantly improved when teachers are aware of the developmental considerations and the research findings on commonly held alternative conceptions.

If We Are Teaching, Why Aren't Our Students Learning?

Research, examination of curriculum materials, and observations of students and teachers point out some of the identified reasons for student confusion and misconceptions:

1. Students' ideas do not always evolve as quickly as the rate of concept presentation in most textbooks and in many teacher-designed units of instruction.
2. Language used by teachers and textbooks may confuse some students.
3. There is often unexplored conflict between students' everyday experiences and the classroom or textbook presentation.
4. Immediate introductions of scientific definitions and formulas (many which are abstract) are not necessarily convincing or meaningful to students if they haven't had sufficient experience with the ideas first. Traditionally many students engage in activities after presentation and discussion about the concept. These activities tend to be verification rather than inquiry-based where students construct an understanding based on observations and evidence they gather.
5. Understanding is often expected before students have a chance to adequately explore and convince themselves of what they have been told. Ideas are often imposed on students, rather than allowing them to have the opportunity to make sense of something by exploring and developing ideas/models over time. "Covering" the curriculum without devoting enough time for building true understanding is counterproductive.
6. Beliefs resulting from personal experience, intuition, and "common sense" lead students to form their own ideas and models, often well before formal instruction. These experiences and feelings seem to contradict what students read in their textbooks and/or are told by their teacher. Even with instruction, it is often difficult for students to give up these ideas, or they may revert back to them later even though it appears they may have "learned" the correct ideas in class.
7. Instruction which fails to identify what students' initial ideas are can leave students' erroneous ideas unchanged. It's similar to a doctor diagnosing an illness. You wouldn't prescribe a course of treatment without examining the symptoms first.

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8. Teachers and schools (even tests!) often erroneously assume that students understand a concept based on the words students use when describing something (e.g.: evaporation). Scientific terminology is not sufficient evidence of learning unless you can ensure that students use the terms with meaning.
9. Demonstrations used by teachers are often passive where students sit back and observe without manipulating materials or experiencing the phenomenon individually or in small groups.
10. Pictures, diagrams, and 2-dimensional models in textbooks and other instructional materials can be misleading, and result in misconceptions.
11. Some common analogies used to explain ideas can cause difficulty because the similarity is not complete.
12. Everyday use of certain terms, often used in nonscientific contexts, contributes to students' confusion. Some words have many different connotations in the English language and the "scientific word" can easily be confused with a common use (e.g.: heat rises).
13. Some ideas are just too abstract and difficult for many students who are still at a concrete learning stage (empty space between atoms and molecules).
14. Memorization of ideas can cause more difficulty, particularly for "academically good students".

Based on and adapted from: Stepan, J. (1994). *Targeting Students' Science Misconceptions*. FL: Idea Factory.

Other resources, tools, and background material that address the research related to student-held misconceptions of science concepts and effective teaching practices can be found at:

National Science Teachers Organization: www.nsta.org. Articles may be found that are relevant to the research and suggest teaching strategies that can address the misconceptions held by students in science.

Science Teachers of Missouri: www.stom.org. Has a Science Misconceptions page under construction. Current research links are zip files.

Kyle, W. C., Jr. & Shymansky, J. A. (April 1, 1989). Enhancing Learning Through Conceptual Change Teaching iIn *Research Matters - to the Science Teacher*, No. 8902. National Association of Research in Science Teaching. Found online <http://www.educ.sfu.ca/narstsite/publications/research/concept.htm>

Webster State University, Ogden Utah, Center for Science and Mathematics Education: <http://departments.weber.edu/sciencecenter/>

Misconceptions in Science

A quick “Google” internet search of any science concept and “misconceptions” will result in multiple website resources.

Recommended resources for teachers to have in their professional library include:

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science: Research into children's ideas*. New York: Routledge

Driver, R., Guesne, E., & Tiberghien, A. (1985). *Children's Ideas in Science*. Philadelphia: Open University Press.

Osborne, R. (1985). *Learning in science: the implications of children's science*. Portsmouth, NH: Heinemann.

What ideas do children hold about the natural world?

How do these ideas affect their learning of science?

Resource: Rosalind Driver Research Linking Tool to Maine's *Learning Results*

http://www.nasalearn.org/teacher_support_alerts.htm

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science: Research into children's ideas*. New York: Routledge

When children start school and through out their school years, they already have preformed ideas about how the natural world works. These ideas may come from within the instructional setting or from their experiences outside of school. Research has shown that teaching is unlikely to be effective unless teachers and curriculum materials take into account learners' preconceptions. Rosalind Driver's book, *Making Sense of Secondary Science: Research into Children's Ideas*, gives a summary of the international research done in the area of students' ideas ranging from age 5 up to age 16. This book is a valuable resource for teachers who want to deepen their understanding of how their students think and learn.

Sampler of Common Identified Misconceptions or Alternative Ideas Linked to Life Science Concepts

Common Misconceptions related to Standard A: Classifying Living Things

Classification:

- a. Trees are only considered plants when they are small.
- b. Criteria such as number of legs, body covering, large size, land habitat, etc. are used to determine whether organisms are animals.
- c. Classification is mutually exclusive rather than hierarchal (example- some students have difficulty accepting that an organism can be classified as both a bird and an animal).
- d. Humans are not animals.

Structural and Behavioral Adaptations:

- a. Organisms intentionally effect changes in body structure to exploit particular habitats.
- b. Organisms respond to a changed environment by seeking a more favorable environment.
- c. Organisms adapt deliberately.

Common Misconceptions related to Standard B: Ecology

Photosynthesis and Respiration:

- a. Plants get their food from the environment rather than manufacturing it internally.
- b. Food for plants is taken in from the outside. Soil supplies most of the “raw materials” for photosynthesis. (Students have difficulty accepting that plants make food from water and air and that this is their only source of food)
- c. Water and minerals are food for plants.
- d. Soil is the plant’s food. People put food (fertilizer) in the soil for plants to eat.
- e. Respiration and photosynthesis are not seen as energy transfer processes.
- f. Plants take their food in through the roots and then store it in their leaves. Plants convert energy from the sun directly into matter.
- g. Plants change water and carbon dioxide into sugar (instead of plants convert carbon dioxide from air and hydrogen atoms from water into sugar).
- h. Plants only give off oxygen.
- i. Photosynthesis is a plant process and respiration is an animal process.
- j. Respiration means breathing (not energy release).

Transformation and Flow of Matter:

- a. Food is a requirement for growth rather than a source of matter for growth (students have little knowledge about food being transformed and made part of a growing organism’s body).
- b. Organisms and materials in the environment are very different types of matter [students have difficulty thinking of the human body as a chemical system and have little knowledge of the elements composing the living body. Animal material (bones, muscle, skin, etc.), plant material (leaves, stems, roots, etc.), and the nonliving environment (water, soil, air, etc.) are seen as fundamentally different and not transformable into each other].
- c. Dead organisms simply rot away and their material “disappears”.
- d. Decay is a gradual, inevitable consequence of time without the need for decomposing agents.
- e. Non-biological processes cause decay/breakdown (for example- the breaking down of an apple may be described as “the rain turned it to mush”)
- f. Processes involve only creating and destroying matter rather than transforming it from one substance to another.
- g. Recycling happens through soil minerals but does not incorporate water, oxygen, and carbon dioxide.

Common Misconceptions related to Standard C: Cells

Cells:

- a. Some students confuse cells with molecules.
- b. Cells are about the same size as molecules, but smaller than some molecules such as proteins and DNA.
- c. Living things contain cells (rather than they are made up of cells).

Microbes:

- a. Students have difficulty conceptualizing microbes as agents of change (example- microbes and decay- they often think decay is an inherent property of the object itself rather than being transformed by microbes).
- b. Microbes are bad-students equate most microbes with disease.
- c. All diseases are caused by “germs”.

Common Misconceptions related to Standard D: Continuity and Change

Natural Selection:

- a. Environmental conditions are solely responsible for changes in traits.
- b. Organisms develop new traits because they need them to survive. Adaptation is a conscious process to fulfill some need or want.
- c. Organisms develop new traits through overuse or under use of certain bodily structures or abilities.
- d. A mutation modifies an individual’s own form during its life rather than only its germ cells and offspring.
- e. Changing a population results from the gradual change of all individuals in the population (as opposed to the survival of a few individuals that preferentially reproduce).
- f. Adaptations result from some overall purpose or design.

Sampler of Common Identified Misconceptions or Alternative Ideas Linked to Physical Science Concepts

Common Misconceptions related to Standard E: Structure of Matter

Density:

- a. For an object to float, it must contain air
- b. When you change the shape of something, you change its mass
- c. Mass (heaviness) is the most important factor determining whether an object will sink or float (e.g., many students believe a large block of ice will not float because it is “too heavy”)
- d. A clay ball, which will sink in water, will displace more water than a clay boat made out of the ball.
- e. Objects that float on water float on any liquid.
- f. Weight and density are the same thing.

Conservation of Matter:

- a. Air has no weight (mass).
- b. Air is nothing.
- c. Gases are not matter because they are invisible.
- d. When something is burned it is used up and nothing remains.
- e. When nails get rusty they lose weight.

Particulate Matter:

- a. Substances contain particles (like blueberries in a muffin) rather than consist of particles. For example, students think water has particles in it, with water or air between the particles. Similarly, students believe air has oxygen particles in it, with air between the particles.
- b. Particles are comparable in size to cells, dust specks, etc. and they can be seen with an optical microscope.
- c. Particles of the same substance in different states (solid, liquid, and gas) have different properties. (For example, some students believe ice particles are cold and hard, liquid water particles have expanded and are larger and softer, while water vapor particles are very large and squashy)
- d. Liquids have smaller (or larger) and/or softer particles than solids.
- e. Gases have smaller (or larger) and/or softer particles than liquids.
- f. When water evaporates it splits up into atoms of hydrogen and oxygen.
- g. The bubbles in a boiling liquid are bubbles of air.

Common Misconceptions related to Standard H: Energy

Energy Transformation and Conservation:

- a. Stored energy is something that causes energy later. It is not energy until it has been released.
- b. Energy transformations involve only one form of energy at a time.
- c. Energy is not stored in food. Food only gives you energy when you eat it.
- d. Energy is not conserved because it is like a waste product. It gets used up.

Heat:

- a. Heat makes things rise. Things rise because “heat rises” and moves around.
- b. Heat acts as a fluid. It accumulates in one spot until that spot is full. Then that spot “bursts” and heat overflows to other parts of a substance.
- c. Soft things melt more easily than hard things.
- d. Heat is a material substance like air or steam.
- e. Temperature is used to measure heat, and heat is “hot”.
- f. There is no difference between heat and temperature. Temperature is heat.
- g. Heat is a substance which could be added to or removed from an object.
- h. Larger ice cubes have a colder temperature.
- i. Under the same conditions, metal is colder than plastic.
- j. “Cold” is transferred from a colder object to a warmer object; “heat” and “cold” are transferred at the same time.
- k. Some substances cannot heat up (for example, flour, sugar, air)
- l. Metals get hot quickly because they “attract heat”, “suck heat in”, or “hold heat well”.

Light:

- a. A light source and its effects are not separate.
- b. White light is colorless and pure.
- c. A color filter adds color to a white beam.
- d. While light is reflected by mirrors, it remains on other objects (they do not see ordinary objects reflecting light).
- e. The eye is the active agent in gathering light, rather than just being a receiver of reflected light.
- f. Light helps us see simply by illuminating objects and making them visible.
- g. Shadows are independent of the object causing them.
- h. Mixing colors of light has the same results as mixing colors of paint.
- i. Light fills a space (“the room is full of light” or light fills a room as water fills a bathtub)
- j. Light travels to an object, “lights it up”, and stays there.

Common Misconceptions related to Standard I: Motion

Forces:

- a. Constant motion requires a constant force- if you want to keep moving along a horizontal track, you have to keep pushing, otherwise you will run out of force and just stop. This represents a failure to distinguish the role of friction as a separate force.
- b. *Reaction* forces are less real than *real* forces. For example, students are told that when they hit (or exert a force on an object), that object “exerts” a force back. It is difficult for many students to attribute an active word to a passive object. (They believe stationary objects like tables do not exert a force).
- c. All things fall down due to gravity but heavy things always fall fastest.
- d. Objects fall because of two things acting separately- gravity and the weight of an object.
- e. Students do not equate weight with the force of gravity.
- f. If a body is not moving there is no force acting on it.
- g. The amount of motion (speed and distance traveled) is proportional to the amount of force.
- h. If a body is in motion, there is a force acting upon it in the direction of motion.
- i. Force is something that is a property of an object and gets used up.

Sampler of Common Identified Misconceptions or Alternative Ideas Linked to Earth and Space Science Concepts

Common Misconceptions related to Standard D: Continuity and Change

Geologic Time and Change:

- a. The Earth was always as it is now, or that any changes that have occurred must have been sudden and comprehensive.
- b. Glaciers and mountains were single acts of creation – not something formed over time.
- c. Large numbers like a billion are incomprehensible in magnitude to some students.
- d. Dinosaurs and humans existed at the same time.

Common Misconceptions related to Standard F: The Earth

Seasons:

- a. The Earth is closer to the Sun in summer than in winter.
- b. Sunlight “bounces” off objects in winter
- c. The tilt of the Earth’s axis changes the planet’s distance from the Sun throughout the year.
- d. The Earth travels in a highly exaggerated elliptical orbit placing it further or closer to the sun.

Rocks:

- a. Rocks are associated with heaviness. Small rock fragments are stones, not rocks. (Ex: a small piece of pumice would not be considered a rock).
- b. Mountains are associated with “high rocks”.
- c. Soil is the precursor of rocks. It changes from soil to clay to rock.
- d. Minerals are the same as rocks only they are “precious rocks”.

Water Cycle:

- a. Young children think clouds are made of “smoke”.
- b. Rain falls from clouds when they collide and split open.
- c. Rain falls when clouds get cold.
- d. When water evaporates, it just disappears and ceases to exist.
- e. When water evaporates, it immediately goes up to the clouds or into the sun.
- f. Students have a difficult time accepting the idea of invisible particles of water in the air.

Phases of the Moon:

- a. Moon phases result from the shadow of the earth cast on the moon.

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- b. Cloud cover causes moon phases.
- c. The moon is half black and half white and it rotates. As the moon rotates, we see different proportions of these two sides.
- d. The moon emits its own light, rather than reflecting light from the sun.

Scale Size and Distance:

- a. Drawings of the sun, earth, and moon only differ in scale size between half or double each other's diameter.
- b. Distance from the sun is not much different from distance between planets.
- c. Sun and moon are drawn between one to four earth diameters away from earth.
- d. Large distances are very difficult for students to comprehend.
- e. Light years are thought of as units of time rather than distance.

Gravity in Space:

- a. Gravity relates only to things on earth.
- b. Gravity is associated with air. If there is no air, there is no gravity.
- c. There is no gravity in space (including the moon). Everything is weightless in space.